



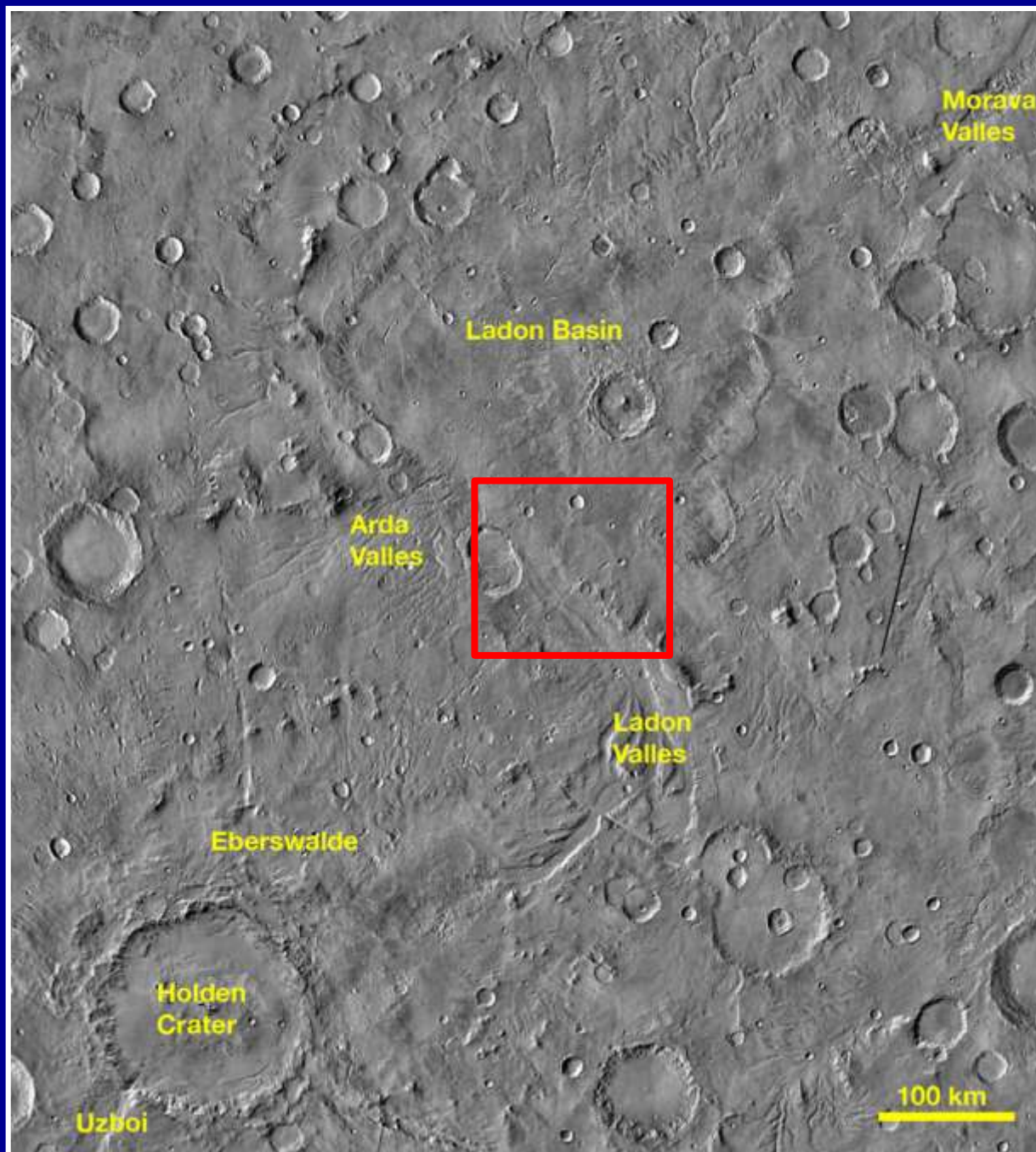
# Investigation of Layered Sediments and Clays at a Proposed Landing Site in Ladon Valles

Catherine Weitz (PSI)

Janice Bishop (SETI/AMES)

John Grant (Smithsonian Institute)



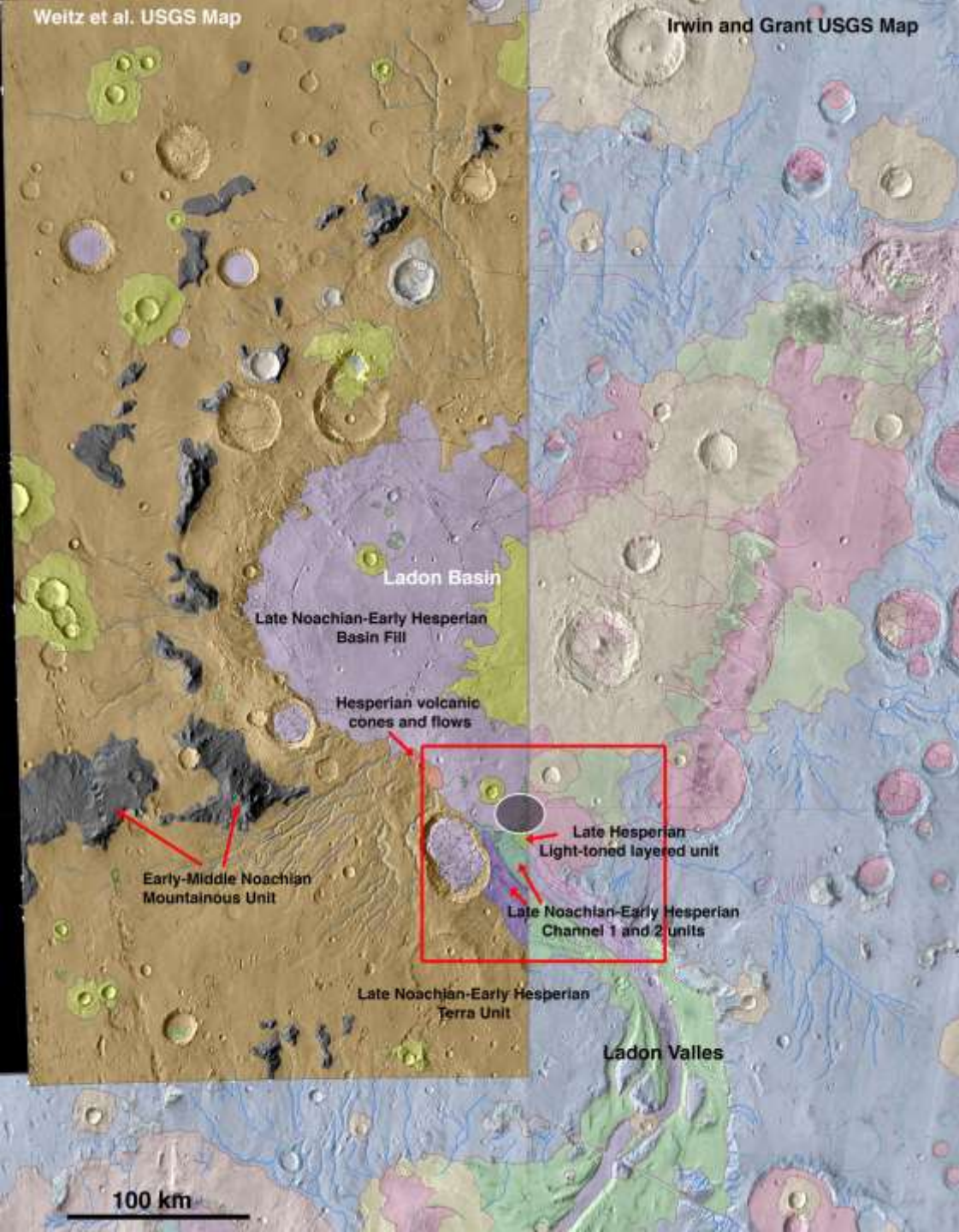


**We propose a landing site at the distal end of Ladon Valles.**

**Ladon Valles is the middle segment in the Uzboi-Ladon-Morava system that formed in the Noachian/Hesperian.**

**The prime science targets include:**

- clays in layered sediments of lacustrine origin**
- altered clays identified in non-layered etched deposit with branching ridges**
- detrital material eroded from upstream Noachian/Hesperian units.**

ellips  
e25x20  
km329.9° E, -  
20.06° N-2.069 km  
MOLA

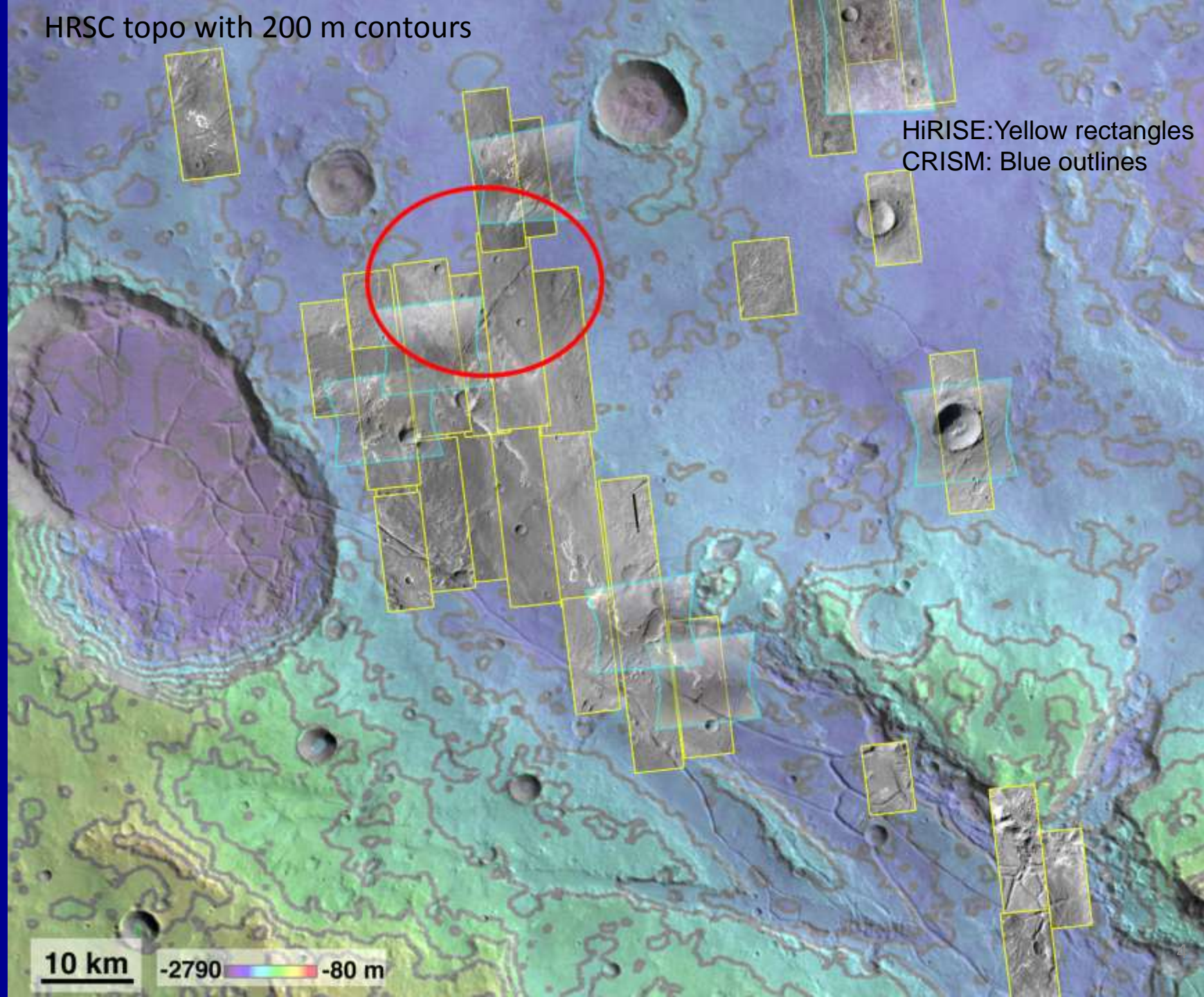
Landing ellipse is situated on boundary between Hesperian/Noachian Channel 2 Unit (HNch2) and Hesperian/Noachian basin fill (HNb) units at distal end of Ladon Valles

Landing site has been shifted further north relative to ellipse presented at 1<sup>st</sup> workshop in order to encompass more regions of interest



HRSC topo with 200 m contours

HiRISE: Yellow rectangles  
CRISM: Blue outlines



10 km

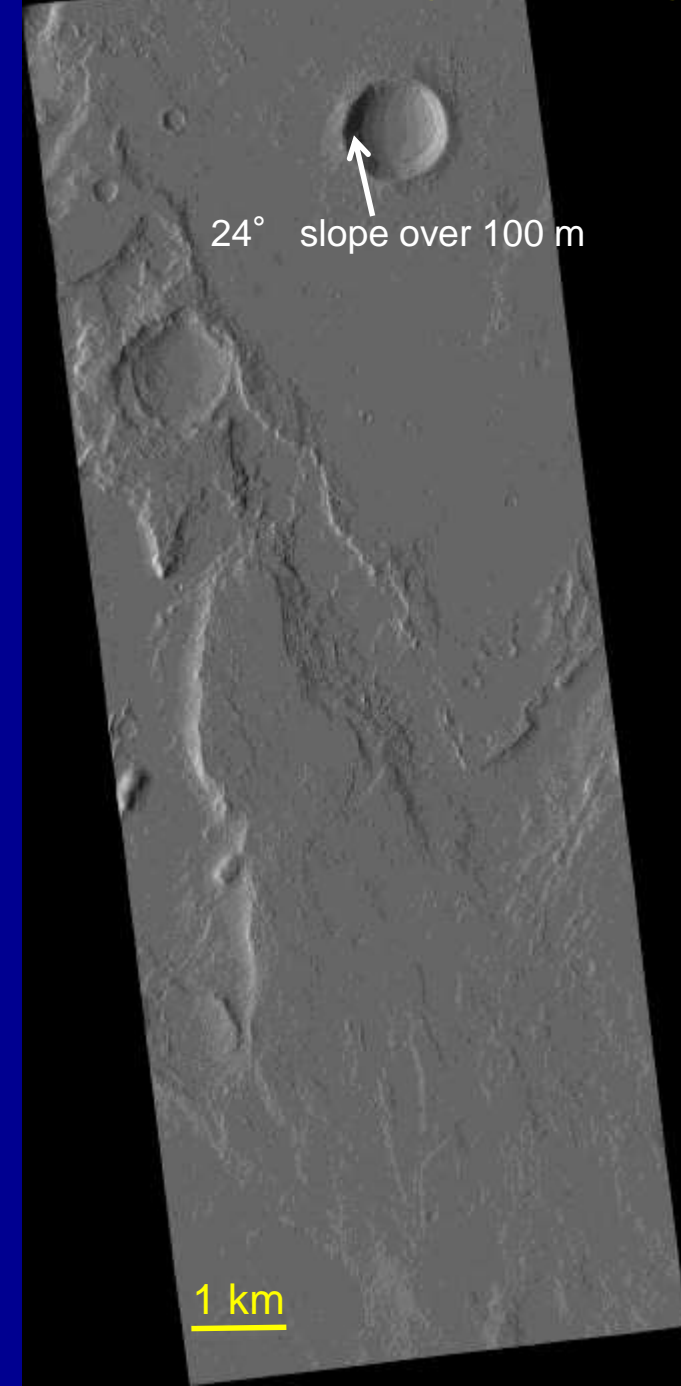
-2790 -80 m

# Engineering Constraints

Parameter	Criteria	Compliance
Elevation	Below 0.5 km	Yes
Latitude	Within $\pm 30^\circ$ of equator	Yes
Slope	$< 20^\circ$ over 2-10 km	Yes
	$< 25^\circ$ over 2-5 m	Some crater walls may exceed
Relief	$< 100$ m over 1-1000 m	Yes
Rock Abundance	Probability of rock 0.55 m tall in area of $4 \text{ m}^2$ is $< 0.5\%$	HiRISE DTMs needed to verify
Thermal Inertia	$> 100 \text{ Jm}^{-2}\text{s}^{-0.5}\text{K}^{-1}$	Yes
Albedo	$< 0.25$	Yes

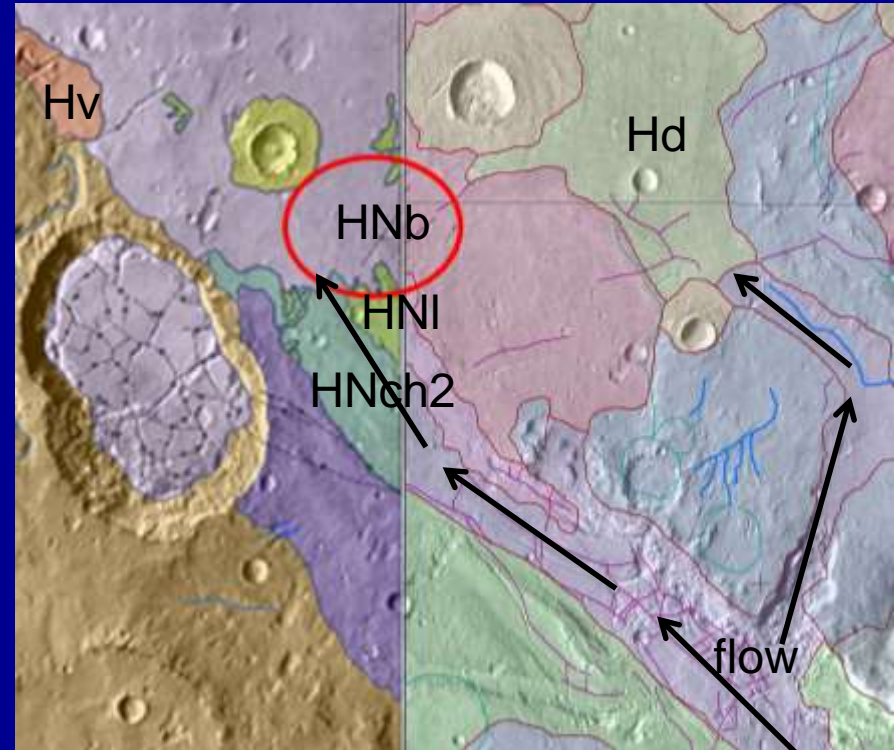
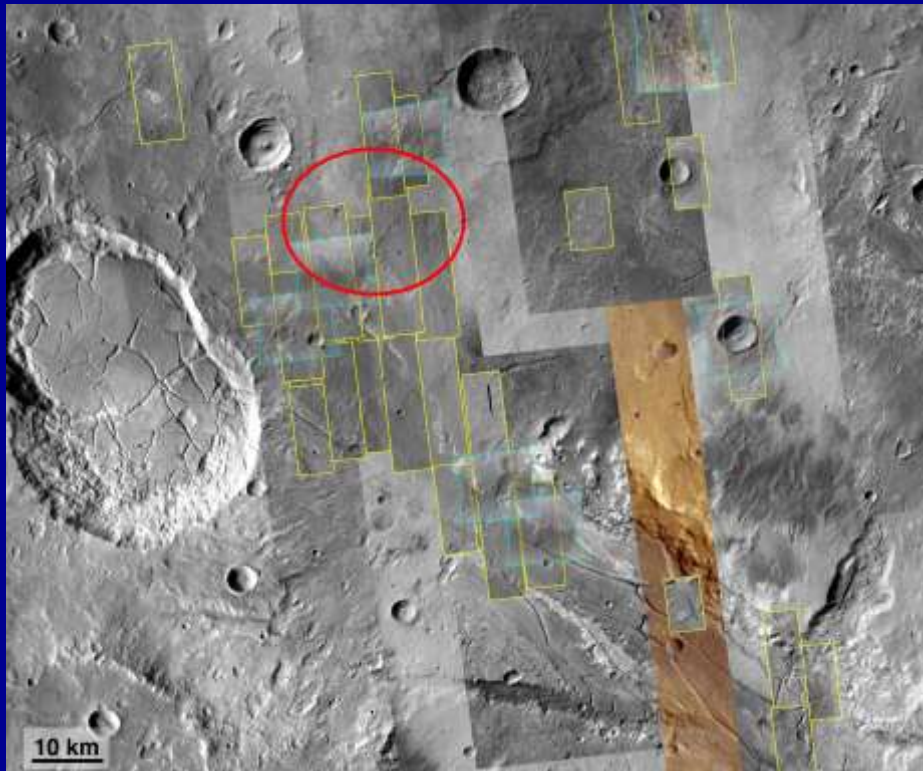
- Terrain Relative Navigation and Range Trigger may not be required for this landing site
- Regions of Interest are within landing ellipse

Hillshade at 5 m scaling  $45^\circ$  sun angle





## CTX mosaic



**Within ellipse are geologic units:**

**HNb (Late Noachian to Early Hesperian basin fill)**

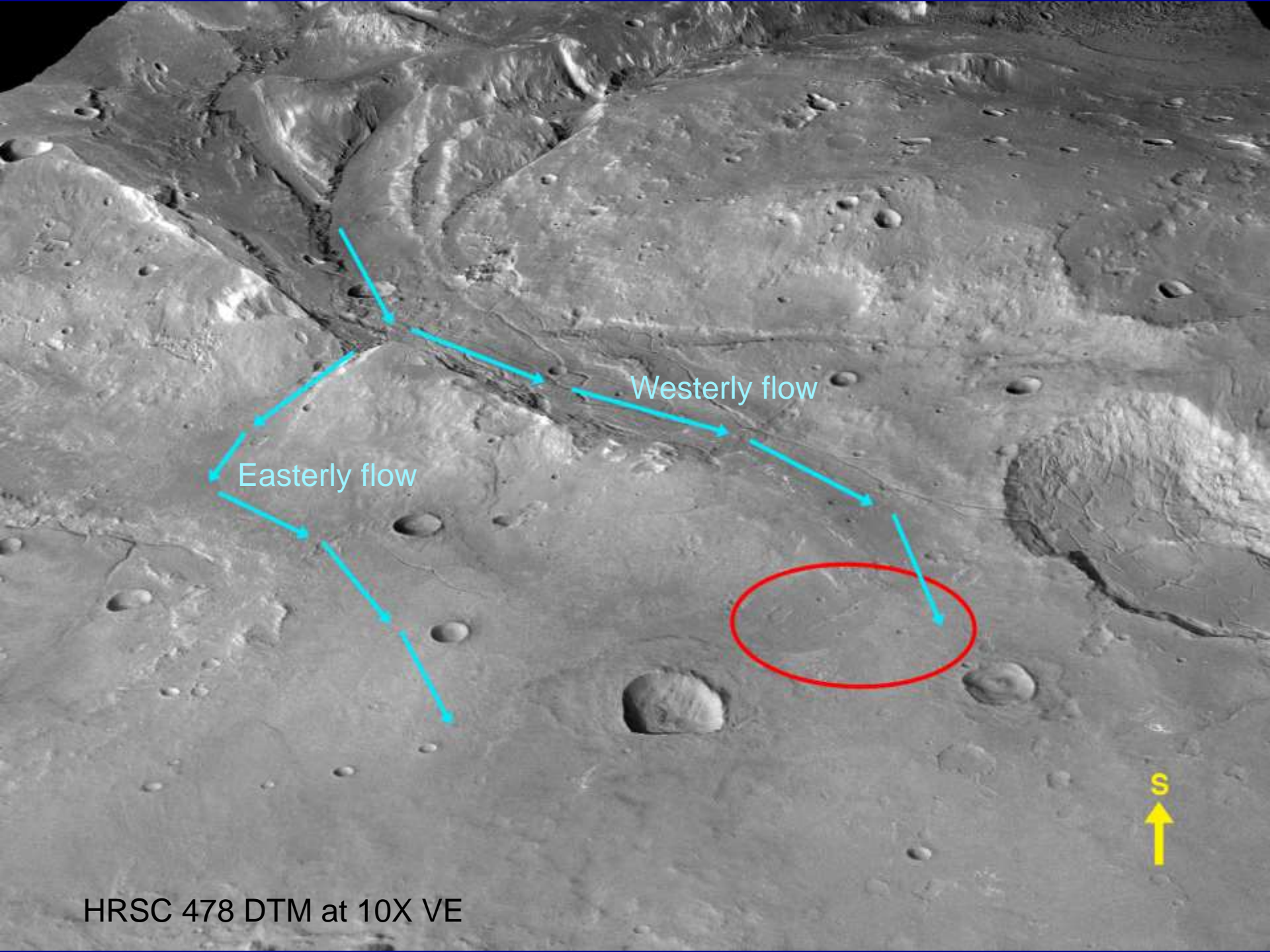
**HNch2 (Late Noachian to Early Hesperian channel)**

**HNI (Late Noachian to Late Hesperian light-toned layered phyllosilicate-bearing deposit)**

**Of interest outside of ellipse are geologic units:**

**Hv (Hesperian volcanic cones and lava flows)**

**Hd (Possible deltaic deposit with clays, appears to extend into ellipse)**



Easterly flow

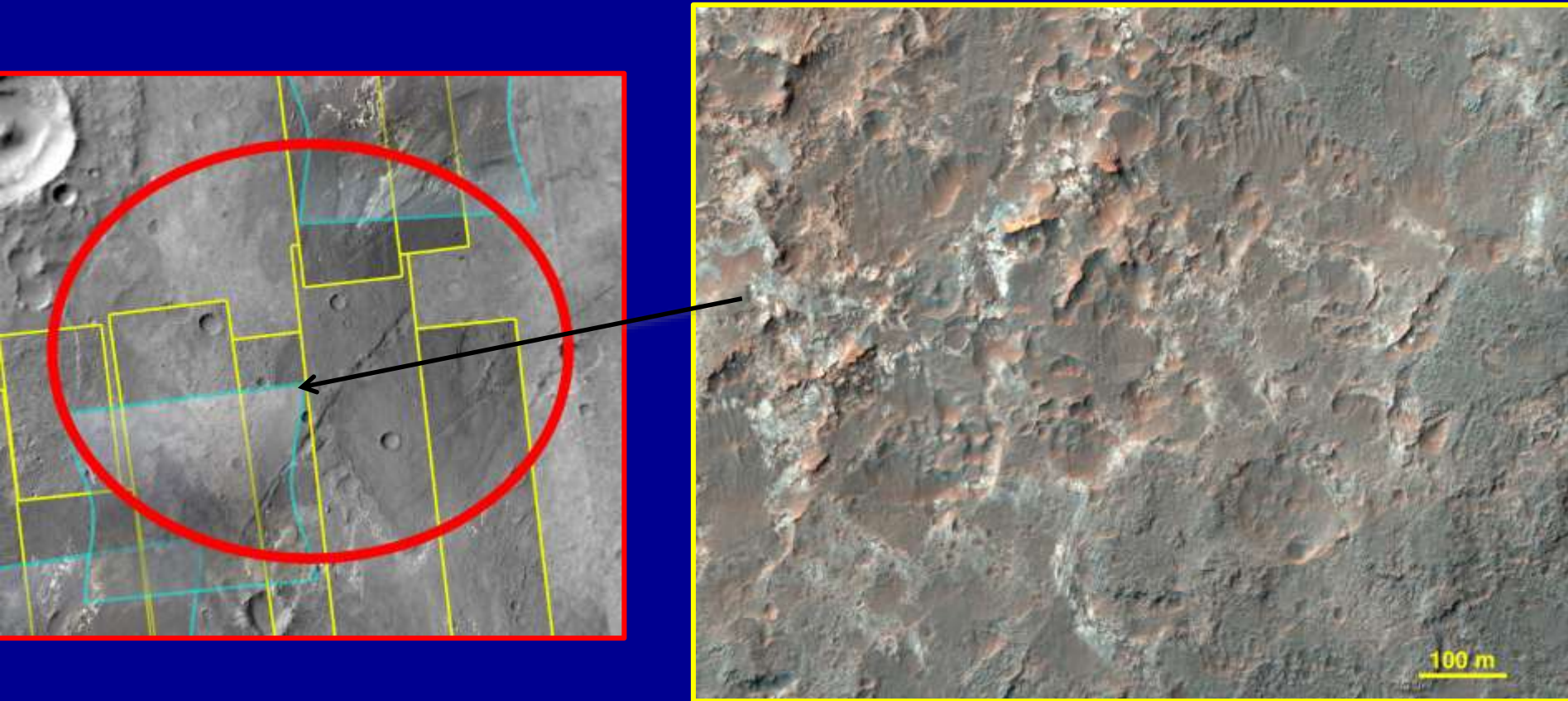
Westerly flow

S  
↑

HRSC 478 DTM at 10X VE



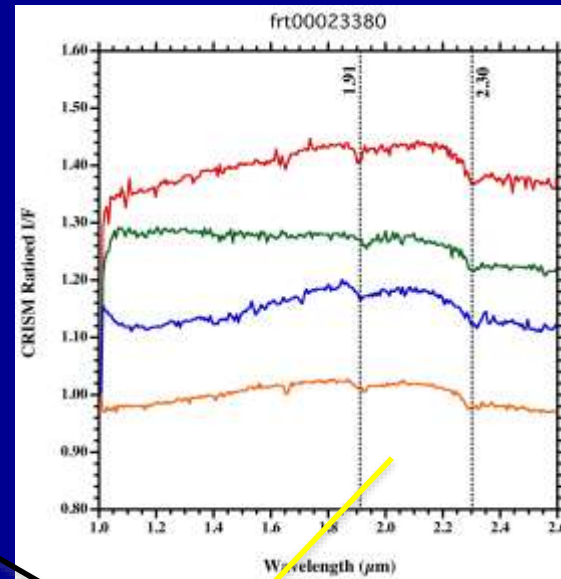
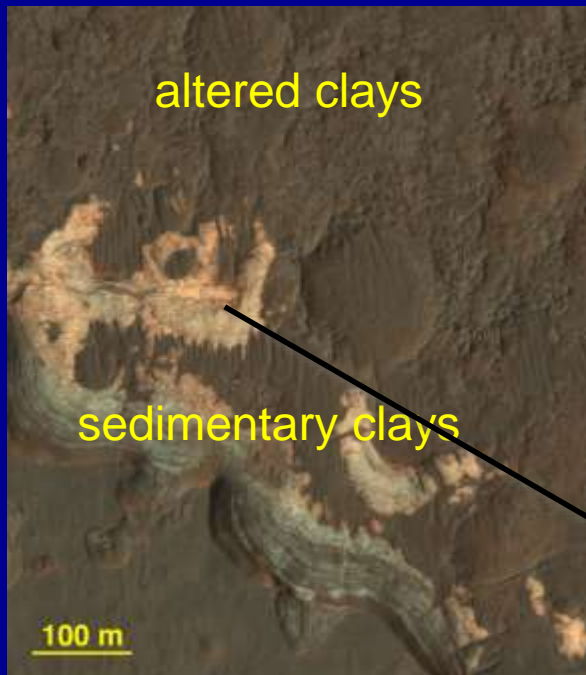
## Example of terrain in center of ellipse



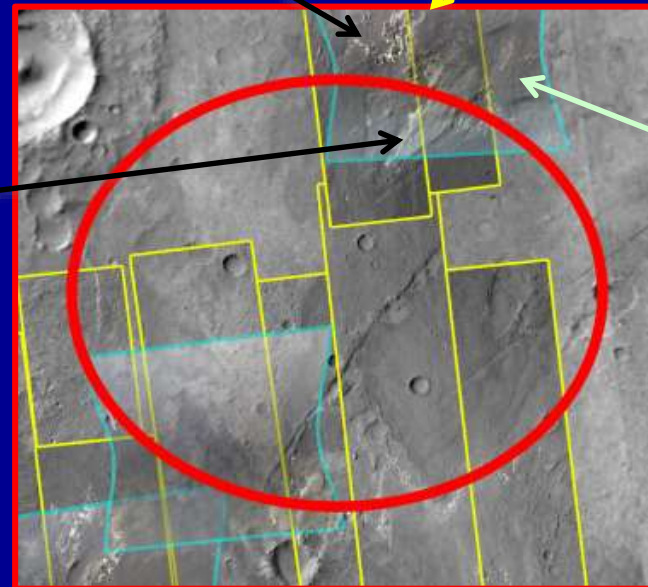
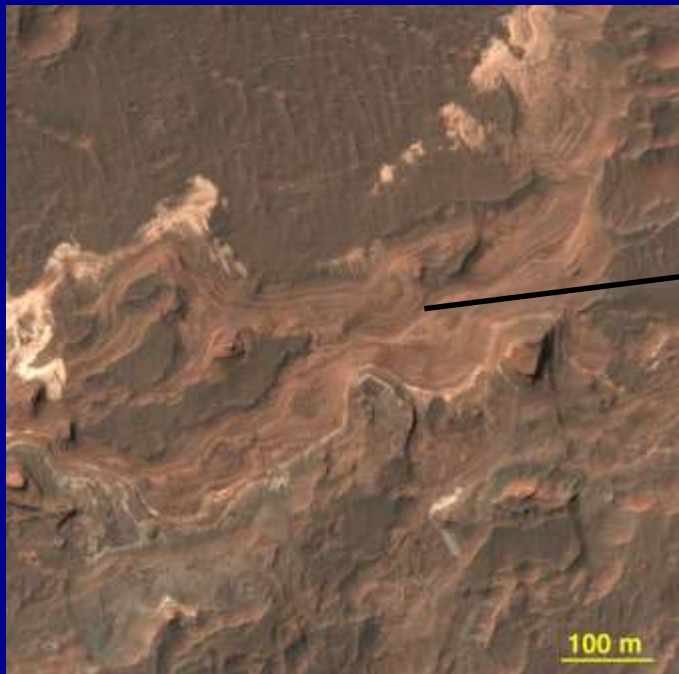
**Etched terrain, very few ripples, and numerous light-toned outcrops indicate easy access and unhindered driving by the rover to different rock types**



**Examples of finely layered clay-bearing sediments and altered clays in northern portion of ellipse  
Could be part of unit HNI**

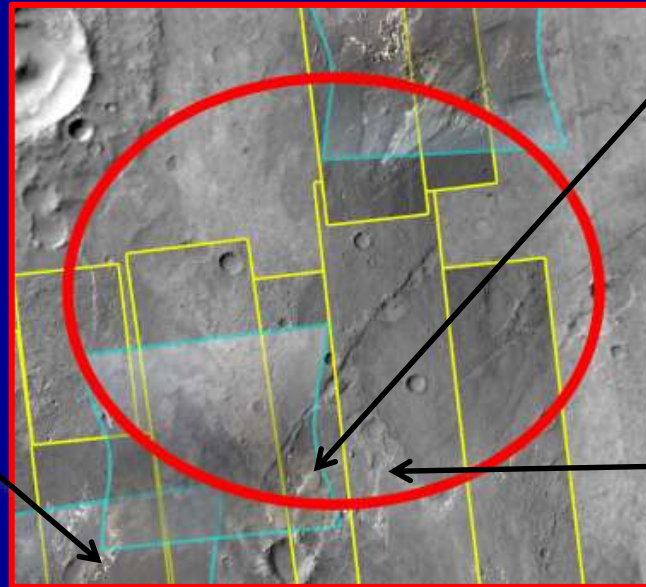


Nontronite  
Saponite



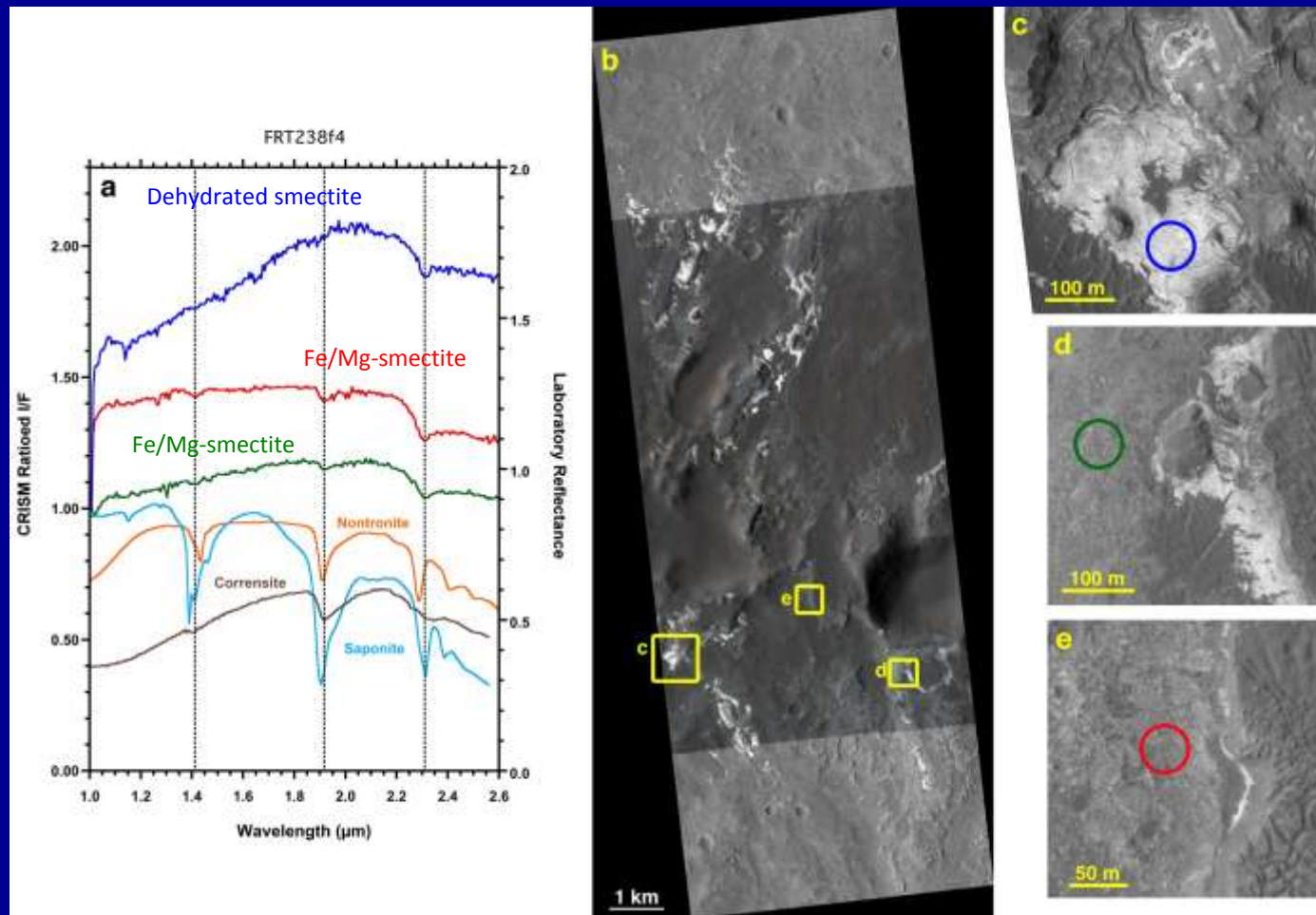
Impact ejecta  
from 10 km  
diameter  
Amazonian  
crater likely  
present in  
ellipse

**Example of geologic unit HNI (light-toned layered phyllosilicate-bearing deposit) in southern portion of ellipse**



- Layered sediments (HNI) appear to have covered much of the distal portion of Ladon Valles before erosion removed much of the unit
- HNI retains very few small craters → recent exposure
- Holden secondaries disrupt HNI (Late Hesperian) and HNI was deposited on Ladon Valles floor (Late Noachian) so age of HNI bounded between these two events
- HiRISE images of beds exhibit color and brightness variations, suggesting variable lithologies



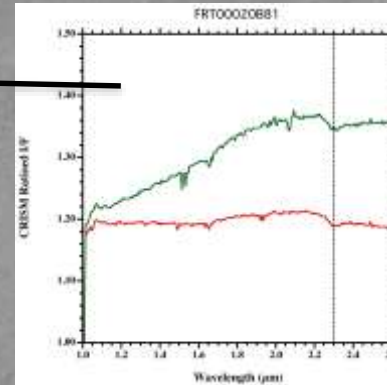


- Lowestmost and brightest beds in HNI have CRISM spectra indicating a Fe/Mg-smectite lacking hydration feature at 1.9 μm (dehydrated) → see blue spectrum in (a) and blue circle in (c)
- Upper beds in HNI are not as well exposed so more difficult to determine their composition, although some are Fe/Mg-smectites with 1.9 μm hydration band
- Because most beds in strata are too small to resolve in CRISM spectra, there could be numerous other compositions present than those observed by CRISM
- Fe/Mg-smectites are also present along upper surface of older basin fill/Ladon Valles floor that lies beneath unit HNI → see red&green spectra in (a) and red&green circles in (d,e)

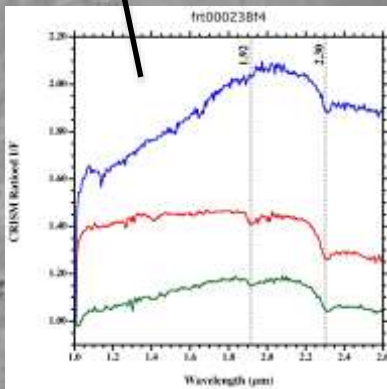
CRISM spectral parameters are  
R=Olivine Index, G=D2300, B=BD1900

ellipse

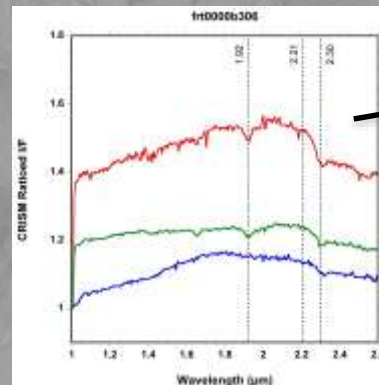
HNI



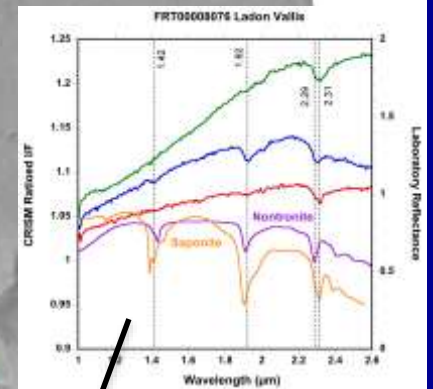
Dehydrated clays



Saponite  
Dehydrated clays

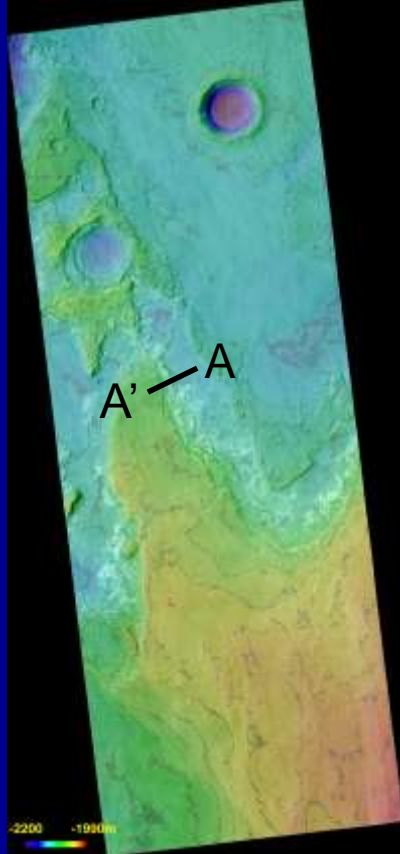


Nontronite  
Saponite  
Dehydrated clays

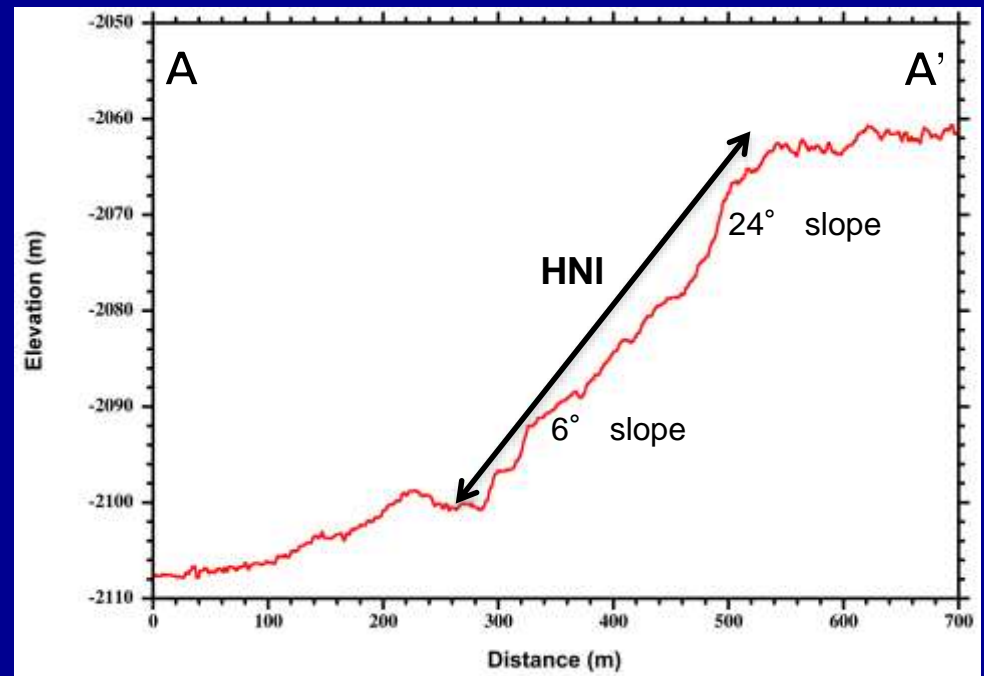


Nontronite  
Saponite  
Dehydrated clays

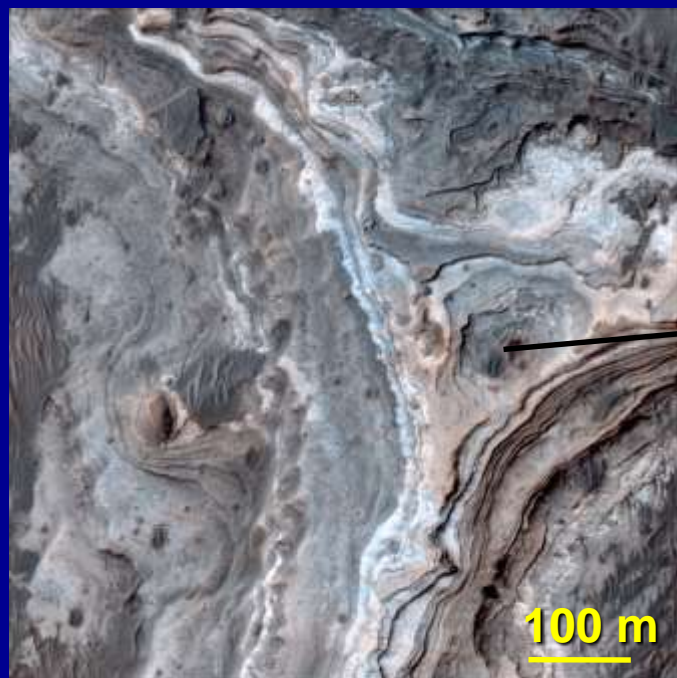




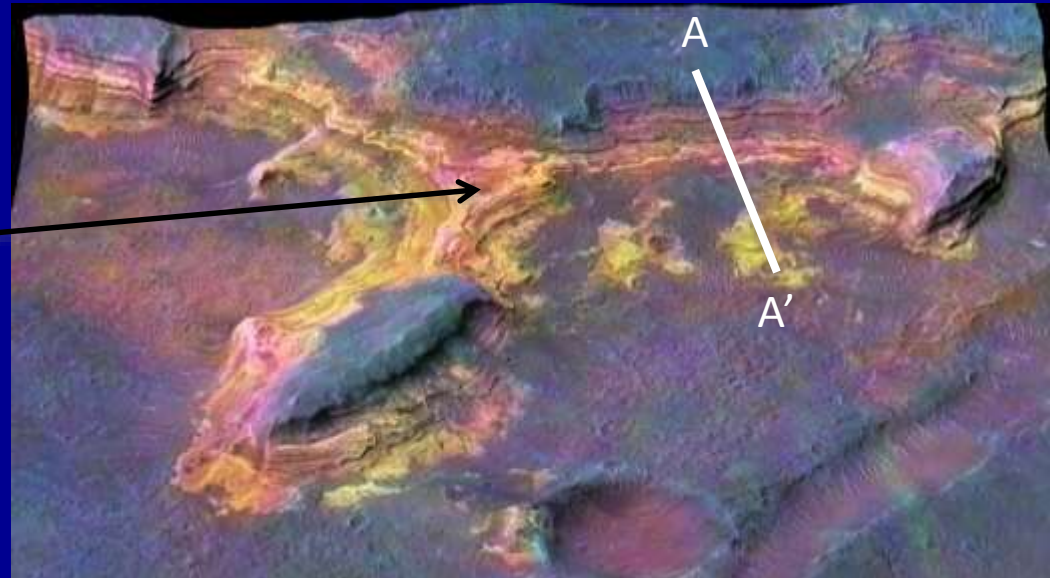
~40 m thick exposure of unit HNI in ellipse



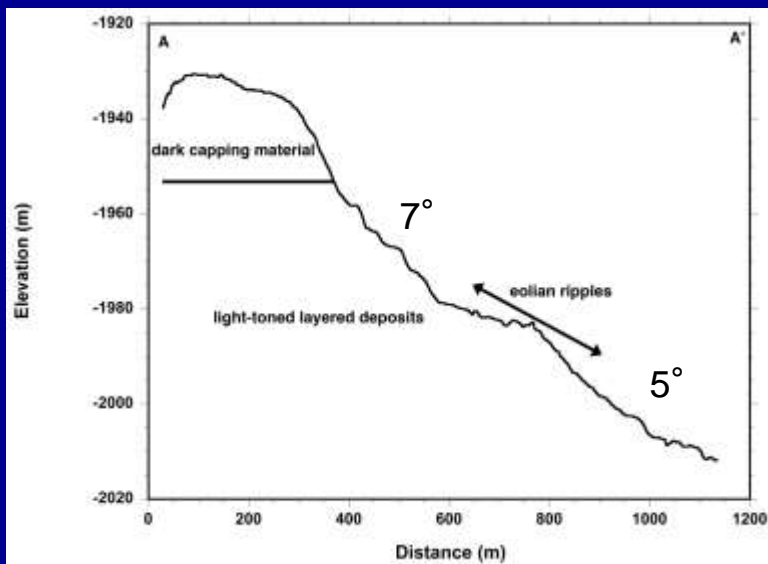
Another HiRISE DTM covers HNI unit to the southeast of ellipse



HiRISE enhanced color

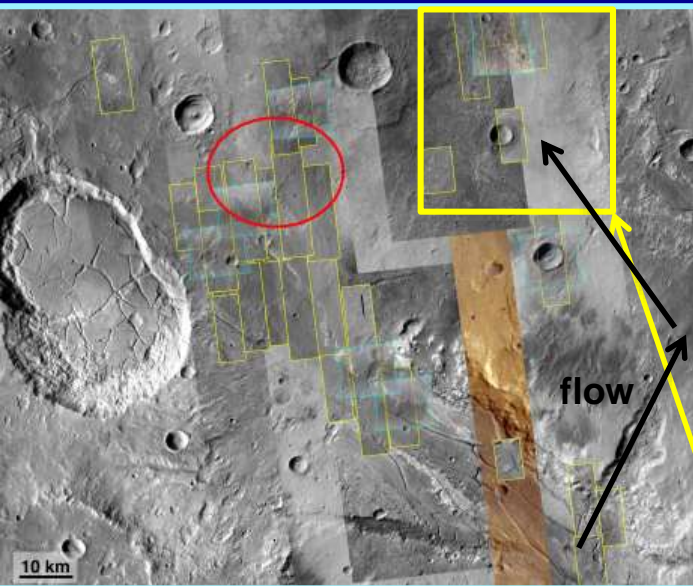


CRISM spectral parameters overlain on HiRISE DTM at 5X vertical exaggeration

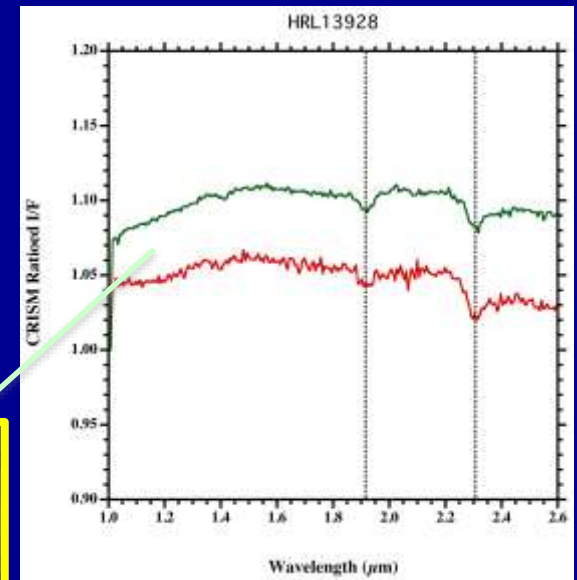


- Topographic profile AA' shows a 65 m thick sequence of exposed layered beds within unit H1, with most beds only a few meters thick.
- The beds appear horizontal as they can be traced across the same elevation for several kms. Bedding slopes derived from DTM are 1-4° , consistent with deposition in a lacustrine setting.
- Surface slopes are 5-7° so traversable by rover

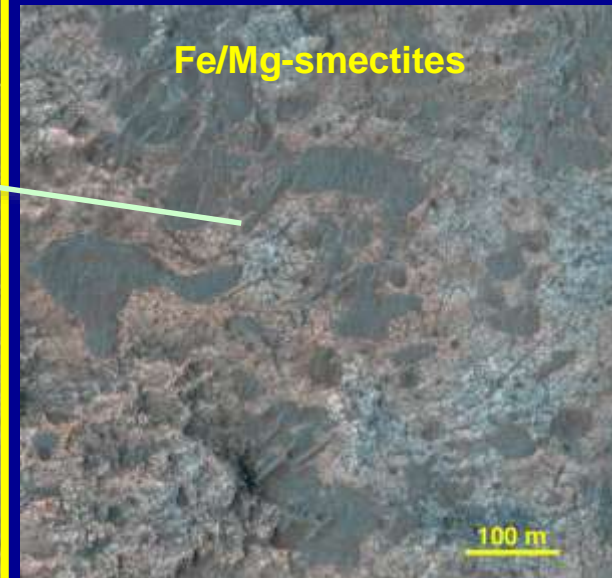
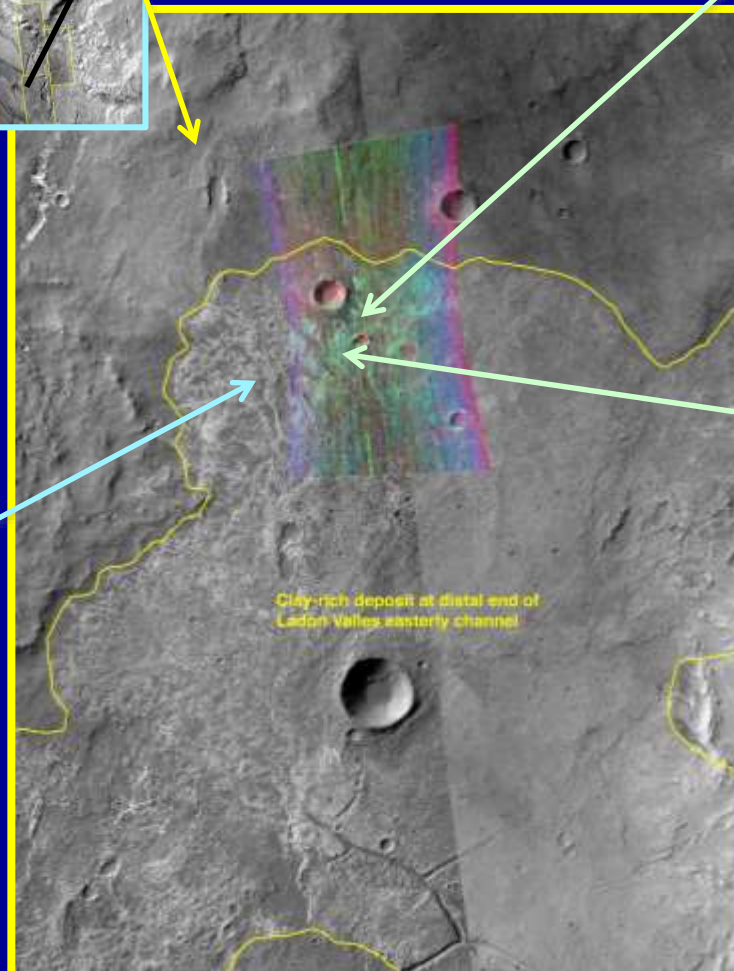




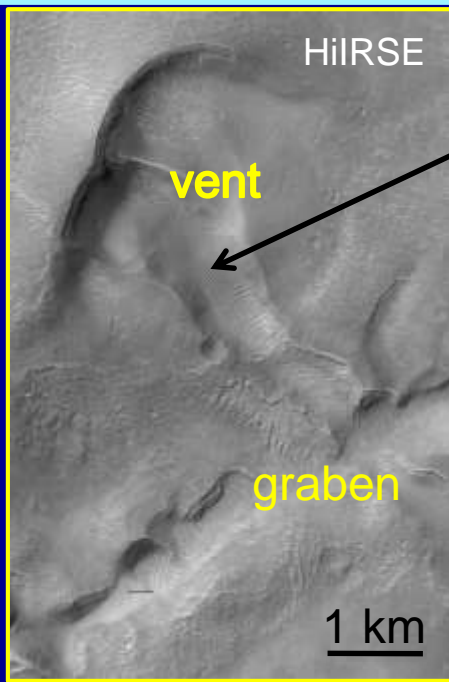
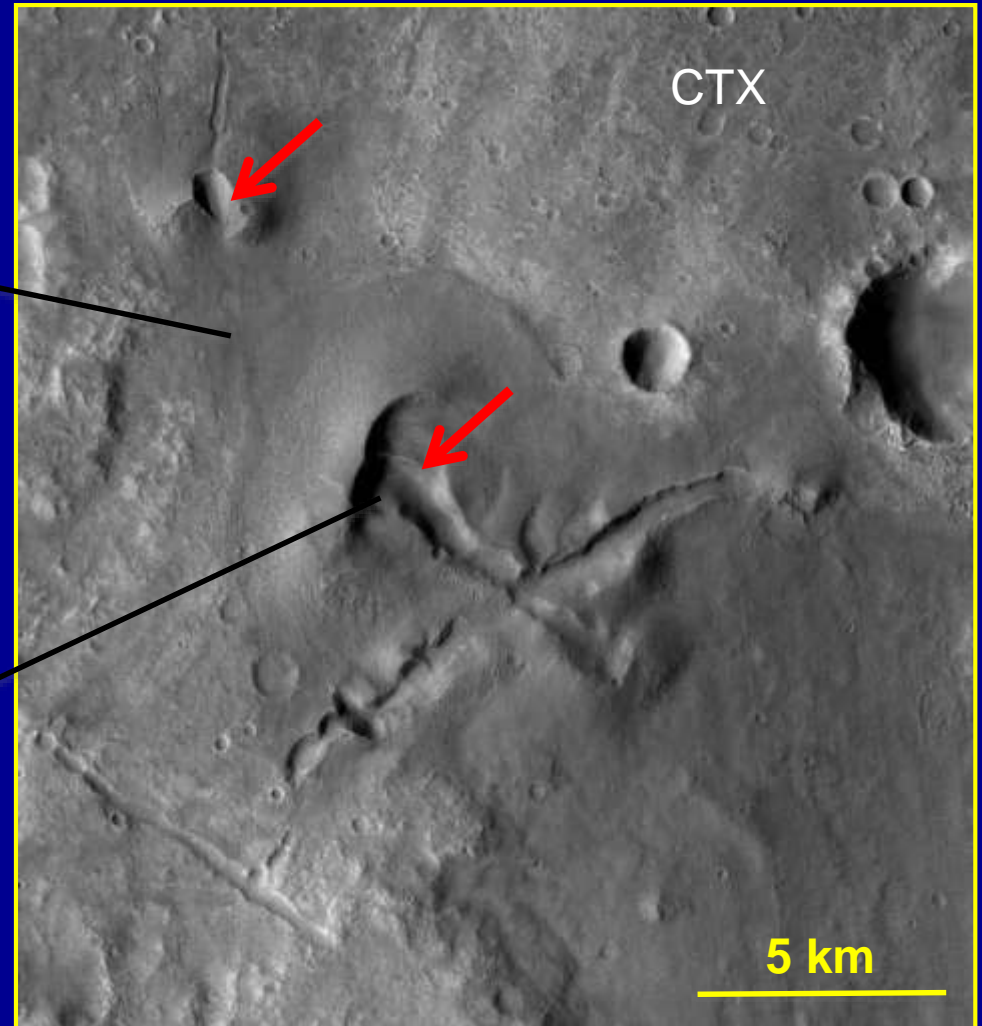
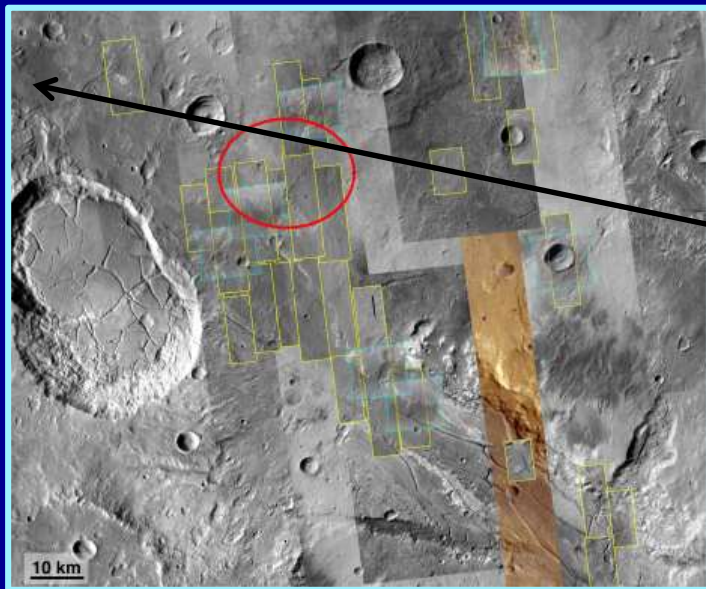
In eastern portion of ellipse and continuing eastward is a clay-rich deposit with few or no layers, likely altered



Branching ridges consistent with flow out of Ladon Valles → distributaries?

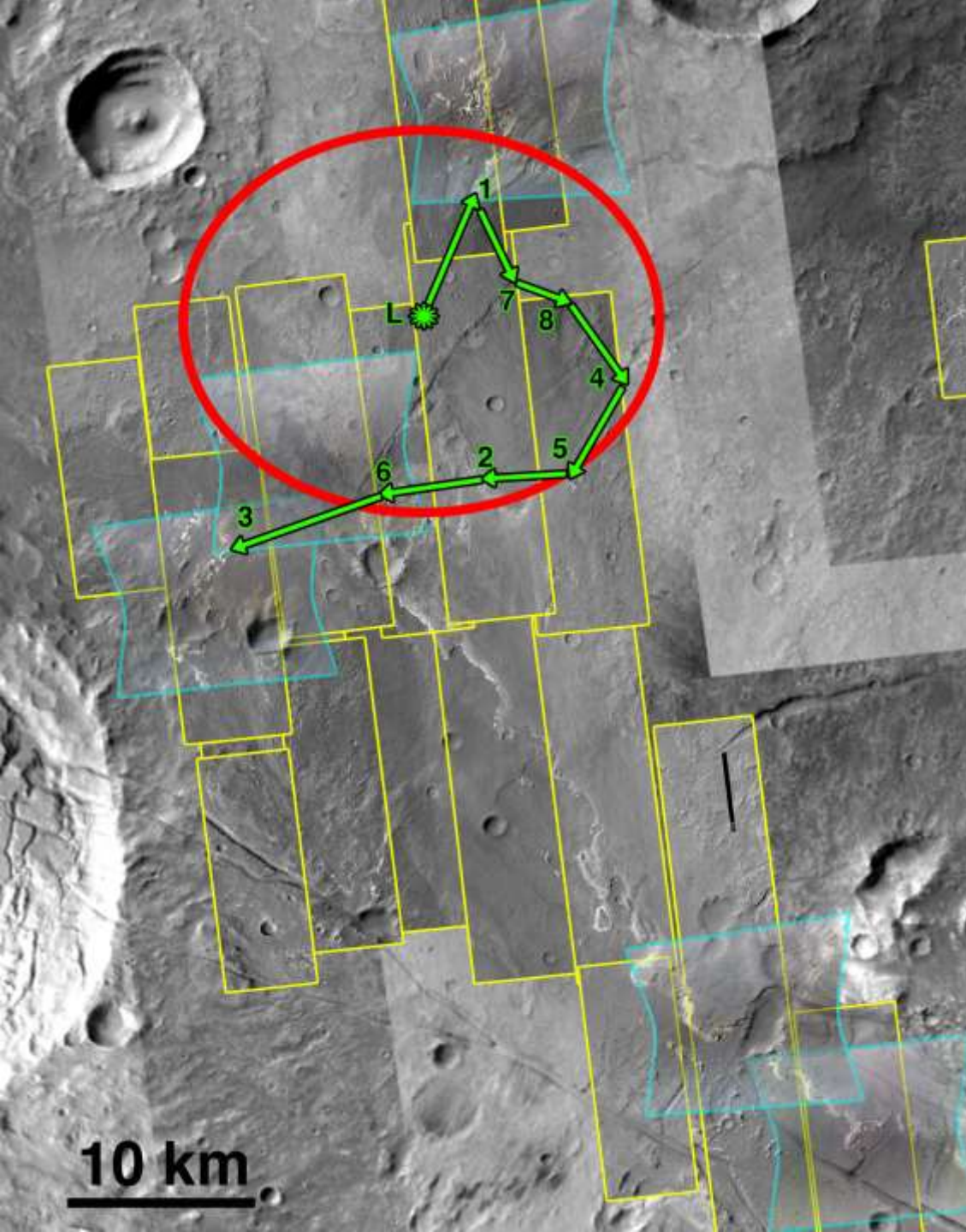


To the west (~25 km) of the landing ellipse are Hesperian age volcanic cones and lava flows



- Additional Hesperian volcanic flows may exist within or closer to ellipse but have not yet been identified from orbit
- Other dark units exist closer to ellipse and could be lava flows





## Regions of Interest

Numbers indicate priority order

Arrows indicate possible rover traverse

L=Landing at center of ellipse

1=Light-toned layered deposit containing clays, ejecta from 10-km-diameter Amazonian crater

2=Lacustrine layered sediments containing clays

3=Lacustrine layered sediments containing clays, possible igneous rocks, Noachian rocks exposed within Ladon Valles channel

4=Etched unit with clays, possibly a delta or fluvial deposit from easterly Ladon Valles channel

5=Lacustrine layered sediments containing clays

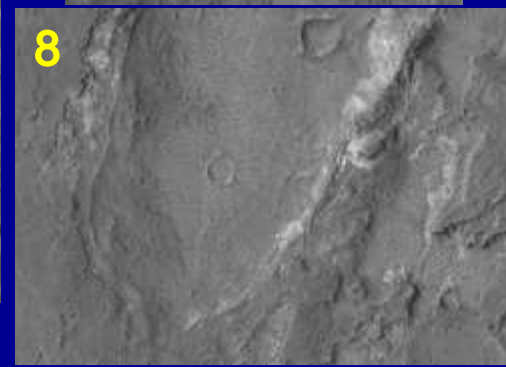
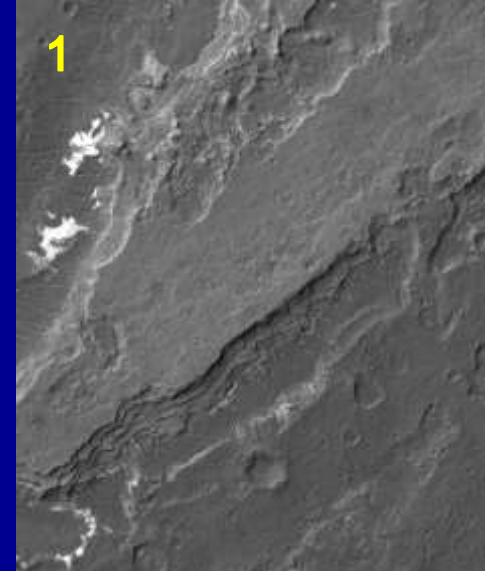
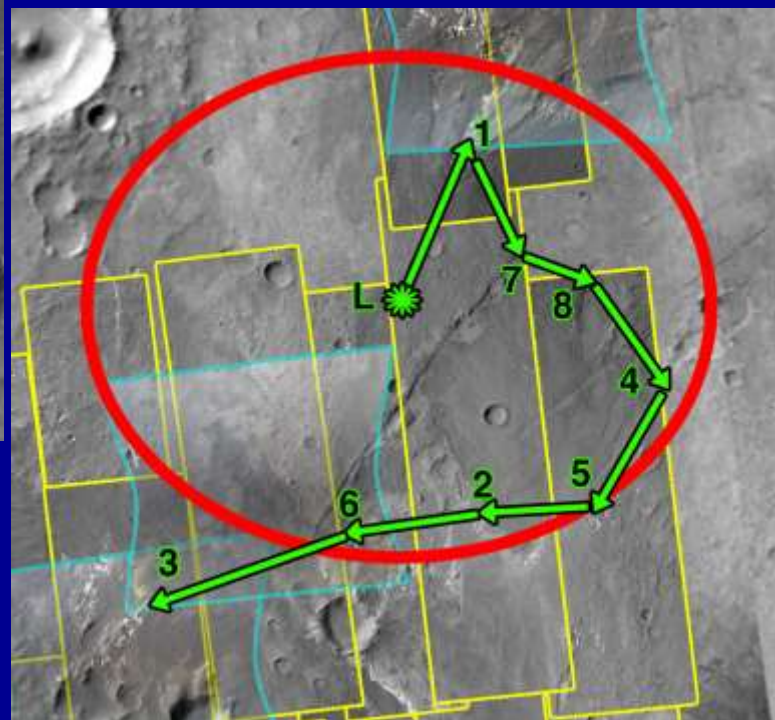
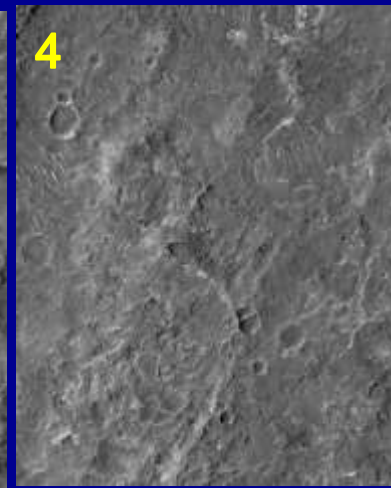
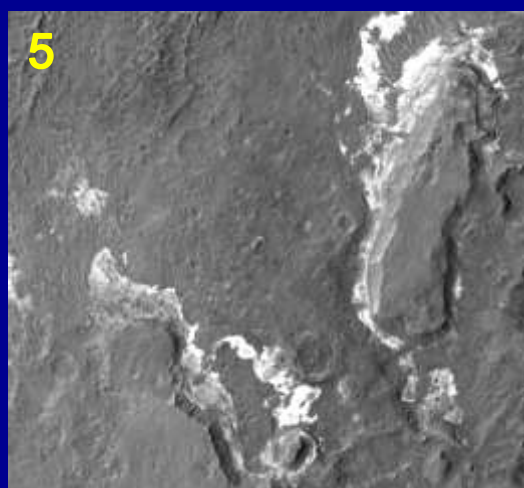
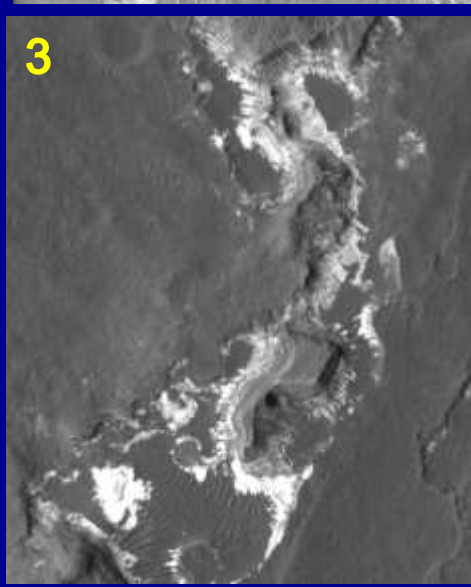
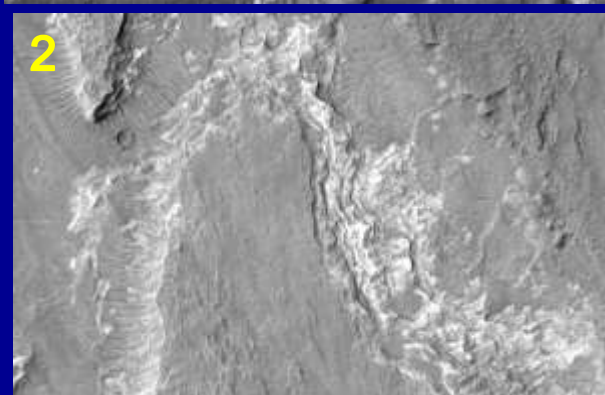
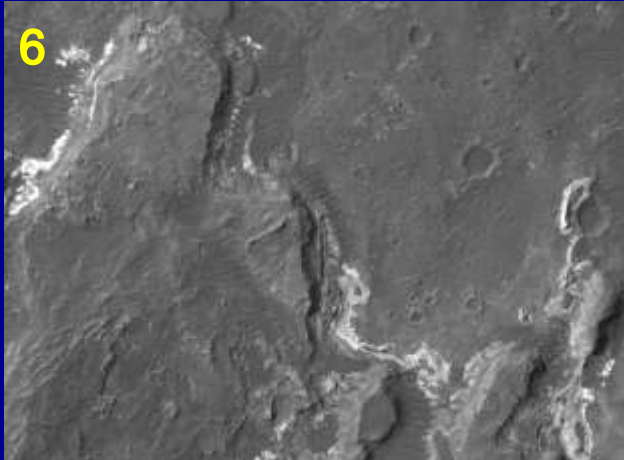
6=Lacustrine layered sediments containing clays

7=Graben exposing deeper deposits within Ladon basin

8=Oval depression exposing deeper layers

After location 3, would continue in southeastern direction moving upstream along Ladon Valles floor towards more exposures of HNI

**10 km**





Landing Site Factor	Mars 2020 Mission and Decadal Priority Science Factors																							
	Environmental Setting for Biosignature Preservation and Taphonomy of Organics								Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages							Type 2 Samples: Igneous		Context: Martian History Sample, Timing Constraints						
	Deltaic or Lacustrine (perennial)	Lacustrine (evaporitic)	Hydrothermal (<100°C) surface	Hydrothermal (<100°C) subsurface	Pedogenic	Fluvial/Alluvial	No diagenetic overprinting	Recent exposure	Crustal phyllosilicates	Sedimentary clays	Al clays in stratigraphy	Carbonate units	Chloride sediments	Sulfate sediments	Acid sulfate units	Silica deposits	Ferric Ox./Ferrous clays	Igneous unit (e.g. lava flow, pyroclastic, intrusive)	2nd Igneous unit	Pre- or Early-Noachian Megabreccia	Oldest stratigraphic constraint	Youngest stratigraphic constraint	Stratigraphy of units well-defined	Dateable surface, volcanic (unmodified crater SFD)
Ladon Valles	●	●	●	?	?	●	?	●	?	●								○	?	?	EN	EA	●	○

Key	
●	Yes (in-ellipse)
○	Yes (out of ellipse)
	No
~	Partial Support or Debated
?	Indeterminate
	TBD

- Shallow dips across 100 kms supports lacustrine origin for HNI
- Branching ridges and clays at distal end of easterly Ladon Valles channel could represent deltaic/fluvial setting
- Sampling of numerous different sediments likely produced in lacustrine setting
- Lack of 1.9µm hydration band in some CRISM spectra indicate dehydration of clays by heating (hydrothermal)
- Etched surface, little dust or ripples, few craters on HNI→recent exposure



- Crustal phyllosilicates may have been transported into site by Ladon Valles flow
- Could be numerous other mineralogies than the Fe/Mg-smectites in HNI but too small to resolve in CRISM
- At least 3 different types of clays are present within and around landing ellipse:
- Clays that appear to represent alteration within deltaic and/or fluvial deposits from Ladon Valles
- Clays that represent lacustrine sediments formed during the Late Noachian-Hesperian (HNI)
- Dehydrated clays formed in hydrothermal environment or by other heating event

- Diversity of rock types transported through Ladon Valles and deposited within landing ellipse during the Late Noachian to Early Hesperian
- Sampling of older Noachian rocks and possible impact breccias exposed by Ladon basin formation in early-mid Noachian
- Landing site permits exploration of units dating from early Noachian (Ladon basin formation) to Amazonian (craters, ripples)
- Stratigraphy of units is well-defined (geologic mapping, crater age dating, DTMs)
- Hesperian effusive igneous unit (Hv) occurs outside ellipse but smaller volcanic units may exist within ellipse
- Igneous rocks likely within landing site based upon dark upper materials similar to Hv and erosion+transportation of igneous rocks by Ladon Valles